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Edible insects - new meat alternative: a review

Ядливи насекоми - нова алтернатива на месото: обзор

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ABSTRACT

Nowadays, the challenge of finding food capable of meeting the needs of the population in terms of availability, nutritional value and sustainability is not only a necessity, but also an aspiration for a healthier lifestyle. The replacement of vertebrate animal products with new protein sources in human nutrition is a topic of increasing interest. Many studies have shown that insects, as a possible food source, have great potential to be called the "food of the future" because they are rich in high-quality proteins, fiber and fatty acids, mineral elements, vitamins.

Keywords: edible insects, nutritional value, insect proteins, entomophagy, future food

РЕЗЮМЕ

В днешно време предизвикателството за търсене на храна, способна да задоволи нуждите на населението по отношение на наличност, хранителна стойност и устойчивост, е не само необходимост, но и стремеж към по-здравословен начин на живот. Замяната на животински продукти с нови източници на протеини в храненето на човека е тема с нарастващ интерес. Много изследвания показват, че насекомите, като възможен хранителен източник, имат голям потенциал да бъдат наречени „храна на бъдещето“, тъй като те са богати на висококачествени протеини, фибри и мастни киселини, минерални елементи, витамини.

Ключови думи: ядливи насекоми, хранителна стойност, протеини от насекоми, ентомофагия

INTRODUCTION

The growth of the population on a global scale is inevitably associated with an increase in the consumption of food products, in particular those of animal origin.

Insects not only represent a major food source to support wildlife, but are also widely consumed by humans in many parts of the world (van Huis, 2015). Entomophagy is the term used to describe the process of eating insects as food (Gahukar, 2011).Historically, this has been largely restricted, but recently there has been a growing interest in breeding insects for food, both for animals and humans. When raised in suitable environmental conditions, they have a lower carbon footprint than farm animals and require less land and water, and many species can feed on relatively low-quality fodder (van Huis, 2013). Many species of edible insects are often looking as available natural resources, reflecting rich biodiversity. They can be consumed by both animals and humans, used for own needs or for trade in many areas of the world.

The use of edible insects varies according to local preferences, socio-cultural factors and region. The main aim of this review is to promote the use of insects for human consumption and their products as a source of important nutrients and their inclusion in the dietary habits of the population.

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Animal and vegetable protein

In developing countries, where protein-energy malnutrition and micronutrient deficiencies are common, increased consumption of animal products can significantly improve the health status of the population. In China, where meat consumption has increased dramatically in recent decades, there is a need to introduce new sources of high-quality protein (He et al., 2016; Henchion et al., 2017). In general, protein of animal origin (meat, dairy products, eggs, fish and other aquatic animals) is considered the highest quality protein, both in terms of its digestibility and essential amino acid content. Meat and milk not only provide energy and high-quality proteins, but also essential fatty acids, B vitamins, as well as a complex of readily available trace elements, including iron, zinc, calcium (Kliem and Givens, 2011; Wyness, 2016). However, excessive consumption of red meat, especially processed meat, is associated with a number of diseases, such as cardiovascular disease, obesity, type 2 diabetes, metabolic disorders in the body, etc. (Salter, 2013). In addition, farm animals, in addition to being a major user of water supplies (necessary for both direct consumption and feed production), are also a source of pollution, contributing to an 18% increase in greenhouse gases (O'Mara, 2011).

The nutritional value of different types of proteins varies and is determined by the amino acid composition, the ratio of essential amino acids, their interaction with other components and their absorption. The greater amount of essential amino acids leads the greater biological value and quality of the protein. The distribution of amino acids in this ratio is also of prime importance in achieving a good nitrogen balance. The metabolism of amino acids is determined by their share in the synthesis of proteins and their digestibility. In addition, many food labels list the quantity, but not the quality, of the protein present. It is necessary to have at least some indication of its quality, because it is known that it also depends on the processing methods used to obtain the final product, which in many cases adversely affect the nature of these compounds. For example, although the nutritional value of wheat gluten as a pure protein is known, its quality is often degraded when wheat flour is processed into breads or cereals (Yu, 2007).

Globally, the main problem for insufficient energy intake is precisely the quality of the protein consumed. In many foods, especially those of plant origin, low levels of various essential amino acids limit nutritional value. This is especially important for cereals, which are poor or lacking in the essential amino acids isoleucine, lysine, threonine and tryptophan, as well as legumes, which are a limited source of methionine. Since these raw materials are the main source of protein for a large part of the Earth's population, there is a need to overcome of the available problem. For this purpose, various companies in recent years have emphasized the development of new food sources of high-quality protein, necessary for the production of high-energy foods. They apply different technologies for their optimal use, such as a) combining protein sources to create mixtures with an adequate amino acid balance; b) enrichment of low-quality proteins with essential amino acids. Numerous studies have been done showing that people in underdeveloped countries consume more low-quality proteins compared to those living in developed countries (Han et al., 2015).

Human insect consumption

To meet future needs, alternative sources of protein are constantly sought, both for direct human consumption and as feed for farm animals. Vincent Holt's book "Why Not Eat Insects?" 1885 is one of the earliest editions related to entomophagy in the United States, that has been reprinted many times until 2018.

It is interesting to note that since the end of the IXth century, various authors have discussed edible insects and the possibility of their use by humans. In a review of the early literature, Friedrich Bodenheimer's book, 1951 entitled “Insects for Human Consumption” remains to now date the most comprehensive survey of the historical literature on entomophagy (Shockley and Dossey, 2014).

Numerous attempts have been made by entomologists to make insects more attractive. A popular example is

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Ronald Taylor's (1975) book “Butterflies in My Stomach” and its companion recipe guide “Entertaining with insects” (1976) (Taylor, 1975; Taylor and Carter, 1976). Several follow-up cookbooks on entomophagy have been published - “La cuisine des insectes. A la découverte de l'entomophagie” by Gabriel Martinez, a French chef offering professional cooking advice, „Creepy Crawly Cuisine: The Gourmet Guide to Edible Insects“ by Julieta Ramos-Elorduy, „Bugs on the Menu“ by Jo Windsor, „Les insectes comme aliments de l'homme“ by Tango Muyay and other. Others, such as the humorous "Eat-A-Bug, Cookbook," offer readers familiar American recipes such as pancakes, pizza, and soup enhanced by the addition of edible invertebrates (Gordon, 1998). In Leland Howard's publication discussed the practicalities of any new cheap foods, including insects (Howard, 1916).

Entomophagy is accepted and practiced by many cultures around the world and is a major source of nutritious food for many people (Ramos-Elorduy, 2009). The traditional use of insects as food continues to be widespread in tropical and subtropical countries and provides significant nutritional, economic and environmental benefits to the population. Up to 3071 ethnic groups in 130 countries (Ramos-Elorduy, 2009) use insects as a basic food (Durst end Shono, 2010; Srivastava et al., 2009; Yen, 2009a, 2009b). Insects are widespread and are reported to be consumed by populations worldwide except Antarctica (Costa-Neto and Dunkel 2016, Schrader et al. 2016). Many of the world's poorest populations regularly eat insects as part of their diet, especially in Africa, Asia, South and Central America and some parts of Europe (Gahukar, 2011; Manary and Sandige, 2008; Ramos-Elorduy, 2009). A study in Kenya, where malnutrition is prevalent, found that wheat buns enriched with insects were actually preferred by local residents over plain bread (Gahukar, 2011).

The popularity of insect consumption as a food source of animal origin continues to grow (Ash et al., 2010; Crabbe, 2012; Durst end Shono, 2010; Dossey, 2013; Gahukar, 2011; Katayama et al., 2008; Premalatha et al., 2011; Ramos-Elorduy, 2009; Srivastava et al., 2009; van Huis, 2013; van Huis et al., 2013; Vantomme et al., 2012; Vogel, 2010; Yen, 2009a, 2009b). All over the world, a large part of the human population consumes insects as a regular part of their diet. Thousands of edible species have been identified. Globally, the three most commonly consumed insectorder by humans are Lepidoptera (with 36 families and 396 species), Hemiptera (with 27 families and 222 species) and Coleoptera (with 26 families and 661 species) (Bukkens and Paoletti, 2005; Ramos-Elorduy, 2009). Acheta domesticus in the adult phase is among the insects that can be legally marketed in Switzerland as food (whole insects, cut or ground). According to the information provided by the applicant, Acheta domesticus is available for human consumption on the market in the EU, Australia and the USA, as whole insects or as a nutritional ingredient in various food products, e.g. food bars, lollipops, flour, chocolate, etc. (EFSA, 2015).

Initially, in regions of the world dominated by Western cultures, such as North America and Europe, the mass media had a negative influence among the population regarding the consumption of insects. Populations of European origin living in North America have imposed taboos on these types of dietary practices (Looy and Wood, 2006).

Nevertheless, even in Europe and the USA, attention is beginning to focus to the potential benefits of using insects as a major dietary component, especially to supplement or replace foods and food ingredients, and recently there has been an increase in interest in entomophagy in these countries (Durst end Shono, 2010; Gahukar, 2011).

Farming of insects is increasingly common, and if they become an important component of the human diet or animal feed, further research is still needed. A number of safety requirements must also be addressed, including allergenicity and the ability to accumulate toxins or biopathogens (EFSA Scientific Committee, 2015). However, along with other new sources of protein, including algae, fungi and bacteria, insects may find an increasingly important role in the human food chain (Salter, 2019).

Can insects be "food for the future"?

According to Lars-Henrik Lau Heckman of the Danish Technological Institute in Aarhus, young people will soon find eating insect dishes as natural as eating sushi today. For a long time, it has been claimed that insects can be the "food for the future". Although the idea of eating bugs is still unpalatable to most people, Danish scientists predict that insect-based foods could become ubiquitous in Europe within the next decade.

In the prevailing Western cultures, people are used to eating and are willing to eat foods that they perceive as safe and that they are not afraid of. In recent years, there has been progress in research on edible insects in Europe. A Dutch project entitled "Sustainable production of insect proteins for human consumption" is investigating the industrial extraction of insect proteins to be incorporated into a range of food products. In the United States, although entomophagy may be observed informally, there is still a barrier to the use of insects as human food. But recently, cultural acceptance of edible insects has become more widespread in the US, albeit slowly. American news blog Huffington Post reported that insects are the number one in food trend in 2011 (Polis, 2011).

Michaelsen et al. (2009) cite numerous benefits of animal-based foods and in particular their importance for malnourished children. Researchers recommend that these food should contain at least 25–33% nutritional ingredients of animal origin to significantly improve growth rates. They conclude that insects are probably the best source of animal food for humans in much of the world.

A successful step in support of this statement was made when the first authorization for human consumption of insects and for placing on the market in the European Union was given for the dried Yellow mealworm (Tenebrio molitor, Coleoptera: Tenebrionidae). Commission Implementing Regulation (EU) 2021/882 of 1 June 2021 authorizing the placing on the market of dried Yellow mealworm larva (Tenebrio molitor, Coleoptera: Tenebrionidae) as a novel food. The cited regulation is a major boost to the insect farming business and according to the “Arcluster” company the global insect market to exceed $4.1 billion in the next five years, from $473.4 million in 2020.

Nutritional and human health value of insects

Animals, including insects, are important sources of many essential nutrients for humans in much of the world. One example of this is the presence of eight essential amino acids, vitamin B12, riboflavin, the biologically active form of vitamin A (retinol, retinoic acid and retinaldehyde) and several minerals. According to many researchers, animal proteins are superior to those found in plants (Babji et al., 2010). Food of animal origin is important for the nutritional status, growth and recovery rate, and cognitive performance of malnourished children (Neumann et al., 2003). Animal proteins are suitable for people suffering from osteoporosis, they contribute to better digestion, they are necessary for the body's self-preservation, cell metabolism and renewal (Anagnostis et al., 2009; Bukkens and Paoletti, 2005; Hoppe et al., 2008; Michaelsen et al., 2009; Yen, 2009a, 2009b). ccording to a number of researchers, insects have numerous characteristics that reveal their potential benefits as high-energy food for humans (Crabbe, 2012; Dossey, 2013; Durst end Shono, 2010; Gahukar, 2011; Katayama et al., 2008; Premalatha et al., 2011; Ramos-Elorduy, 2009; Srivastava et al., 2009; van Huis, 2013; Vogel, 2010; Yen, 2009a, 2009b). In addition to protein, insects are also rich in fat (Bukkens and Paoletti, 2005; Finke, 2012; Gahukar, 2011), therefore providing a high energy balance. A review by Bukkens and Paoletti concluded that the amino acid composition of insects is comparable to the reference standard recommended by FAO and the World Health Organization. Insects are particularly high in protein, at levels comparable to beef and milk (Table 1). For example, domestic crickets contain approximately 20.5% protein, while beef contains about 25.6% and whole milk powder 26.5% (Bukkens and Paoletti, 2005).

In the research of Bukkens and Paoletti, all insect species were found to be a significant source of the essential fatty acids linoleic and linolenic acid (Bukkens

Table 1. Comparison of the nutritional content and caloric content of selected insects with high protein foods

Insect	Nutritional content				
	Protein (g/kg)	Fat (g/kg)	Thiamin (mg/kg)	Riboflavin (mg/kg)	Calories (kcal/kg)
Blac soldier fly*	175	140	7.7	16.2	1994
House fly**	197	19	11.3	77.2	918
House cricket**	205	68	0.4	34.1	1402
Superworm**	197	177	0.6	7.5	2423
Mealworm**	187	134	2.4	8.1	2056
Gianty mealworm**	184	168	1.2	16.1	2252
Waxworm**	141	249	2.3	7.3	2747
Silkworm**	93	14	3.3	9.4	674
Beef***	256	187	0.5	1.8	2776
Pork, chop****	181	317	12	2.1	3530
Mutton, chop****	200	48	1.4	2.4	1220
Milk powder*****	265	268	2.6	14.8	4982

* Finke (2012)
** Finke (2002)
*** Current USDA National Nutrient Database for Standard Reference
**** Ahmad (2018)
***** From the US Dairy Export Council website
Beef: ground, 75% lean meat and 25% fat, patty, cooked, broiled, milk, whole dry powder (black soldier fly = Hermetia illucens larvae; house fly = Musca domestica adults; house cricket = Acheta domestica adults; Superworm= Zophobas morio larvae; mealworm or giant mealworm = Tenebrio molitor larvae; Waxworm = Galleria mellonella larvae; silkworm = Bombyx mori larvae).

and Paoletti, 2005). Some insects can also provide a higher caloric contribution to the diet than soybeans, corn, or beef (Gahukar, 2011). The fatty acid content of insects is similar to that of poultry and fish, even some insects are much richer in linoleic and/or linolenic acid, which are the main fatty acids. In addition to protein, fat and caloric content, many insects are particularly rich in a number of vitamins, minerals and other valuable nutrients (Ayensu et al., 2019; Patel et al., 2019). For example, in various types of insects, the content of thiamine and riboflavin is much higher than in chicken eggs and whole grain bread. The content of retinol (a biologically active form of vitamin A) and beta-carotene in many insect species is also high, with levels in some species reaching 1800 mg/kg (Bukkens and Paoletti, 2005). Currently, however, there is very limited data on vitamin assays in insects, so more studies are needed.

Some studies have found cases where insect pests in the region of Mexico and Nigeria possess high nutritional qualities and can have significant positive impacts on human health in areas where malnutrition is high, as well as economic benefits (Banjo et al., 2006). Christensen et al. (2006) identified edible insects in the Kenya region as a source of minerals. Deficiencies of important minerals such as iron, zinc and calcium are often widespread among people in developing countries. This is due to the low amounts of minerals in staple foods such as grains and legumes and the lack of animal foods higher in these nutrients. As a result, entomophagy may prove to be a valuable measure to combat iron and zinc deficiency in developing countries. Certain caterpillars (the larvae of butterflies) have been found to be a rich source of iron, copper, zinc, thiamine (vitamin B1) and riboflavin (vitamin B2); 100 g of cooked insect provides over 100% of the

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daily requirement of each of these minerals and vitamins (Christensen et al., 2006).

Edible Insects- processing and safety

The use of insects as a source of human food involves two important technological challenges: how to turn insects into safe, healthy at the same time palatable food products, and how to cheaply, efficiently and sustainably to produce enough insects to meet market demand.

Populations that regularly eat insects and foods based on them consider them useful and view them as nutritional, medicinal, ecological, sustainable and safe products. When insects become more widely accepted as a promising food product in industrialized countries, the economic consequences will have a significant positive impact on business, industry and research. Partial replacement of vertebrate-produced foods and nutrients with insect-derived ones will significantly reduce the environmental impact, mainly on greenhouse gas production and water consumption, compared to conventional livestock farming. In addition, their breeding is economically more profitable, due to the possibility of using biowaste (La Barbera et al. 2020).

As in the creation of any new food product, as well as in the development of foods incorporating insects, considerable attention must be paid to their safety. There are quite a few people around the world who consume significant amounts of insects without suffering adverse health effects. But there is a potential risk in the use of insects in food, which can be minimized with proper technological processing. Otherwise, it is possible to have digestive problems, irritation of the intestinal mucosa, toxic effects or allergic reactions. In addition, some people have a fear of insects and are sceptical about their consumption (De Marchi et al., 2021).

The insects that are put into food, in one form or another are whole, uncleaned from the digestive tract and its contents in most cases (Shackleton and Shackleton, 2004). For this purpose, it is imperative to apply reliable processing methods, such as pasteurization, to destroy bacteria and their spores and reduce microbial contamination. And as insects become a more popular and widely used food ingredient, the regulations for their use need to be updated, especially in the United States. To ensure the safe and effective use of insects as food ingredients, especially in developing countries where appropriate equipment and processing methods are difficult to access, educational programs and materials with recipes and processing methods are needed (Amadi et al., 2005).

In recent times, there has been a trend for growing of the market for edible insects and insect-based food products around the world. In the USA, mostly Latin American and Asian restaurants offer insects on their menus (Durst end Shono, 2010; Gahukar, 2011). A number of companies in the US are taking advantage of this emerging market in its early stages and are undertaking the development of insect-based food products. However, security-related technologies and the introduction of new market requirements take time to develop and refine to an industrial scale. Therefore, it is important that research teams consider and develop the most viable products with which this emerging industry can launch. After the preparation of regulated technological documentation for the production of various food ingredients from insects, they can be incorporated into numerous products, e.g. in different types of snacks, in protein-enriched bars, as meat substitutes, in food mixes, etc. (Dossey, 2013).

Conducting research and education programs on the safe selection, rearing and preparation of insects for human consumption where the level of malnutrition is significant can significantly improve the nutritional status and overall health of the people who live there. The inclusion of insects in food could greatly improve the prospects of the food industry and lead to a dramatic increase in their demand and cultivation as human food ingredients.

There are very few literature studies related to the processing of insecticides, which necessitates the development and application of processing methods and their incorporation into standard foods, both at industrial and household levels. In many areas of the world,

especially in places where poverty and malnutrition are highest, the main methods of their preparation involve roasting or frying whole insects. Individuals of many species die naturally with the onset of winter (at least in temperate and subtropical zones), and the consensus among insect chefs is that the most humane and efficient way to kill them for food use is by freezing. Subsequently, their processing involves using whole insects or grinding them into a paste or powder.

Replacing vertebrate meat with protein-rich meat-like products from insects does not dramatically change our diet. You don't have to give up the delicious meat products that many people enjoy, including tacos, hotdogs, and breaded meatloaf (chicken and fish). With some small innovations, most (or all) of them can be made from insects. This can be achieved in part by using processes similar to those used to make vegetarian or vegan meat substitutes from plant protein - tofu, tempeh (soy foods), etc. Insect protein behaves similarly to protein in other meats, having a similar texture and flavor when cooked. Many popular vertebrate products, such as hot dogs, sausages, ground beef (for tacos, etc.), chicken nuggets, and others, contain significant amounts of fillers and other non-meat ingredients, as well as seasonings to enhance their flavor. Similarly, with minimal research and development to apply existing methods of producing meat and meat substitutes, insect meat products can be obtained quite easily. Some US companies are already developing strategies to make these alternative insect-derived meat products feasible (Shockley & Dossey, 2014).

CONCLUSIONS

Recent years have seen an increase in interest to the nutritional and health benefits of eating edible insects and their potential contribution to maintaining a well-balanced diet. Production of foods with a balanced protein composition by incorporating insects, a new alternative source of protein, is expected to increase worldwide.

To realize the potential benefits of human consumption of insects, it is necessary that the technologies for the use of edible insects be fully studied and generaly regulated. This allows new and detailed research to be carried out in this area to improve their production and preservation techniques, to adherence of safety requirements, including allergenicity and the ability to accumulate toxins or biopathogens, for the correct implementation of all regulations.

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